

JAPANESE PATENT PUBLICATION (A)

(11) Publication number: 2002-020838
(43) Date of publication of application: 23.01.2002

(51) Int.Cl. C22C 38/00
C21D 9/46
C22C 38/16

(21) Appln. no.: 2000- (71) Applicant: NIPPON STEEL
357753 CORP
(22) Date of filing: 24.11.2000 (72) Inventor: OKAMOTO TSUTOMU
UEJIMA
YOSHIYUKI
TANIGUCHI
YUICHI
TOMOKIYO
TOSHIMASA

(30) Priority
Priority 2000133418 Priority 02.05.2000 Priority JP
number: date: country:

(54) LOW CORROSION RATE AND HIGH STRENGTH HOT ROLLED STEEL
SHEET EXCELLENT IN HOLE EXPANSIBILITY AND DUCTILITY, AND
ITS PRODUCTION METHOD

(57) [ABSTRACT]

[PROBLEM] To provide a low corrosion speed high strength
hot rolled steel sheet having a 590N/mm² or higher tensile
strength and having an excellent hole expansibility and
ductility.

[MEANS FOR SOLUTION] Containing, by wt%, C: 0.01 to 0.20%,
Si: 0.05 to 1.5%, Mn: 0.5 to 2.5%, P: 0.03 to 0.2%, S:
0.009% or less, Cu: 0.1 to 1.0%, Ni: 0.1 to 1.0%, N: 0.010%
or less, Mg: 0.0005 to 0.01%, Al: 0.002 to 0.07%, and one

or both of Ti: 0.003 to 0.25% and Nb: 0.003 to 0.04%, having a balance of iron and unavoidable impurities, and further controlling the oxides to make the steel structure containing MgO having a particle size of 0.005 μm to 5.0 μm in range or composite oxides of one or more of Al_2O_3 , SiO_2 , MnO , and Ti_2O_3 containing MgO in an amount of 1.0×10^3 to 1.0×10^7 per square mm mainly a ferrite structure and the remainder a bainite structure.

[CLAIMS]

[Claim 1] A low corrosion speed high strength hot rolled steel sheet excellent in hole expansibility and ductility characterized by containing, by wt%,

C: 0.01% to 0.20%,

Si: 0.05% to 1.5%,

Mn: 0.5% to 2.5%,

P: 0.03% to 0.2%,

S: 0.009% or less,

Cu: 0.1% to 1.0%,

Ni: 0.1% to 1.0%,

N: 0.010% or less,

Mg: 0.0005% to 0.01%,

Al: 0.002% to 0.07% and

one or both of

Ti: 0.003% to 0.25% and

Nb: 0.003% to 0.04%,

having a balance of iron and unavoidable impurities, making the steel structure containing MgO having a particle size of 0.005 μm to 5.0 μm in range or composite oxides of one or more of Al_2O_3 , SiO_2 , MnO , and Ti_2O_3 including MgO in an amount of 1.0×10^3 to 1.0×10^7 particles per square mm mainly

a ferrite structure and making the remainder a bainite structure.

[Claim 2] A low corrosion speed high strength hot rolled steel sheet excellent in hole expansibility and ductility characterized by containing, by wt%,

C: 0.01% or more,

0.20% or less,

Si: 0.05% to 1.5%,

Mn: 0.5% to 2.5%,

P: 0.03% to 0.2%,

S: 0.009% or less,

Cu: 0.1% to 1.0%,

Ni: 0.1% to 1.0%,

N: 0.010% or less,

Mg: 0.0005% to 0.01%,

Al: 0.002% to 0.07%, and

one or both of

Ti: 0.003% to 0.25% and

Nb: 0.003% to 0.04%,

having a balance of iron and unavoidable impurities, and making a steel structure containing MgO having a particle size of 0.005 μm to 5.0 μm or composite oxides of one or more of Al_2O_3 , SiO_2 , MnO , and Ti_2O_3 including MgO and precipitates comprised of composite precipitates having these as nuclei around which (Nb, Ti)N is formed and having a size of 0.05 μm to 5.0 μm in range in an amount of 1.0×10^3 to 1.0×10^7 particles per square mm mainly a ferrite structure and making the remainder a bainite structure.

[Claim 3] A low corrosion speed high strength hot rolled steel sheet excellent in hole expansibility and ductility characterized by containing, by wt%,

C: 0.01% to 0.20%,
Si: 0.05% to 1.5%,
Mn: 0.5% to 2.5%,
P: 0.03% to 0.2%,
S: 0.009% or less,
Cu: 0.1% to 1.0%,
Ni: 0.1% to 1.0%,
N: 0.010% or less,
Mg: 0.0005% to 0.01%,
Al: 0.002% to 0.07%, and
one or both of
Ti: 0.003% to 0.25% and
Nb: 0.003% to 0.04%,
having a balance of iron and unavoidable impurities,
further containing one or both of
Ca: 0.0005% to 0.0100% and
REM elements in total: 0.0005% to 0.0100%,
having a balance of iron and unavoidable impurities,
and making a steel structure containing MgO having a
particle size of 0.005 μm to 5.0 μm or composite oxides
of one or more of Al_2O_3 , SiO_2 , MnO , and Ti_2O_3 including MgO
in an amount of 1.0×10^3 to 1.0×10^7 particles per square mm
mainly a ferrite structure and making the remainder a
bainite structure.

[Claim 4] A low corrosion speed high strength hot rolled
steel sheet excellent in hole expansibility and ductility
characterized by containing, by wt%,

C: 0.01% to 0.20%,
Si: 0.05% to 1.5%,
Mn: 0.5% to 2.5%,
P: 0.03% to 0.2%,

S: 0.009% or less,
Cu: 0.1% to 1.0%,
Ni: 0.1% to 1.0%,
N: 0.010% or less,
Mg: 0.0005% to 0.01%,
Al: 0.002% to 0.07%, and
one or both of
Ti: 0.003% to 0.25% and
Nb: 0.003% to 0.04%,
having a balance of iron and unavoidable impurities,
further containing one or both of
Ca: 0.0005% to 0.0100% and
REM elements in total: 0.0005% to 0.0100%,
having a balance of iron and unavoidable impurities,
making the steel structure containing MgO having a particle
size of 0.005 μm to 5.0 μm or composite oxides of one or
more of Al_2O_3 , SiO_2 , MnO , and Ti_2O_3 including MgO and
precipitates comprised of composite precipitates having
these as nuclei around which (Nb, Ti)N is formed and having
a size of 0.05 μm to 5.0 μm in range in an amount of 1.0×10^3
 1.0×10^7 particles per square mm mainly a ferrite
structure and making the remainder a bainite structure.
[Claim 5] A method of production of low corrosion speed
high strength hot rolled steel sheet excellent in hole
expansibility and ductility characterized by rolling steel
described in claim 1 or claim 2 or claim 3 or claim 4 by a
rolling end temperature of the Ar_3 transformation point or
more, then cooling by a 20°C/sec or more cooling speed, and
taking up the sheet at 350°C to 600°C so as to make the
steel structure mainly a ferrite structure and make the
remainder a bainite structure.

[Claim 6] A method of production of low corrosion speed high strength hot rolled steel sheet excellent in hole expansibility and ductility characterized by rolling steel described in claim 1 or claim 2 or claim 3 or claim 4 by a rolling end temperature of the Ar_3 transformation point or more, then cooling by a 20°C/sec or more cooling speed down to 650°C to 700°C , air cooling at that temperature for 15 seconds or less, then again cooling and coiling at 350°C to 600°C so as to make the steel structure mainly a ferrite structure and make the remainder a bainite structure.

[Claim 7] A method of production of low corrosion speed high strength hot rolled steel sheet excellent in hole expansibility and ductility characterized by adding Si and Mn, then adding Ti, then adding Mg and Al in the steel described in claim 1 or claim 2 or claim 3 or claim 4 and at the step of adjusting the ingredients at a melting stage of the method of production of steel described in claim 5 or claim 6.

[Claim 8] A method of production of low corrosion speed high strength hot rolled steel sheet excellent in hole expansibility and ductility as set forth in claim 5 or claim 6 or claim 7 characterized by using an Mg alloy comprised of one or more of Si, Ni, Cu, Al, and REM (rare earth metal) as a dilute solvent metal of Mg.

[Claim 9] A method of production of low corrosion speed high strength hot rolled steel sheet excellent in hole expansibility and ductility as set forth in claim 8 characterized in that an Mg concentration in the Mg alloy is 1% to less than 10%.

[Claim 10] A low corrosion speed high strength hot rolled steel sheet excellent in hole expansibility and ductility

as set forth in claims 7 to 9 characterized in that a sum of concentrations of Fe, Mn, and Cr in the Mg alloy is less than 10% and a method of production of the same.

[DETAILED DESCRIPTION OF THE INVENTION]

[0001]

[TECHNICAL FIELD OF THE INVENTION] The present invention mainly covers steel sheet for automobiles used press formed and relates to low corrosion speed high strength hot rolled steel sheet excellent in hole expansibility and ductility having a thickness of 1.0 to 6.0 mm or so and a tensile strength of 590N/mm² or more and a method of production of the same.

[0002]

[PRIOR ART] In recent years, as a measure to improve the fuel efficiency of automobiles, chasses are being reduced in weight. There has also been a growing need for reduction of costs by integral formation of parts. Hot rolled high strength steel sheet excellent in press formability is therefore being developed. In the past, as hot rolled steel sheet for working use, steel sheet comprised of a structure mainly comprised of bainite has been proposed. For example, Japanese Patent Publication (A) No. 4-88125 and Japanese Patent Publication (A) No. 3-180426 propose methods of production of hot rolled steel sheet excellent in hole expansibility comprised of a structure mainly comprised of bainite. Further, Japanese Patent Publication (A) No. 6-293910 proposes a method of production achieving both hole expansibility and ductility by using a two-stage cooling process so as to control the ferrite ratio. These steel sheets excellent in hole expansion are mainly used for chassis parts of automobiles. However, with the

increasingly lighter weight of automobile chassis parts, not only hole expansion and other workability, but also corrosion resistance is being sought. Chassis parts suffer from problems such as salt damage due to road salt, moisture from the roads, and chipping due to flying gravel, so are parts suffering from the worst corrosion conditions even at the chassis. In the past, as measures against this, the parts have been designed with greater thickness so as to give a safety margin against rust. As rustproof steel sheet, in general galvanized steel sheet, one type of surface treated steel sheet, is used, but chassis parts are arc welded, so at the time of welding, the zinc vaporizes and forms gas bubbles which are entrained inside the welding bead and form weld defects (blow holes). For this reason, for chassis parts, steel sheet increased in the corrosion resistance of the steel itself is being sought. As steel sheet with material corrosion resistance, in the past, steel sheet to which Cu, P, etc. have been added has been reported (Japanese Patent Publication (B2) No. 60-32709). Further, while Japanese Patent Publication (A) No. 7-118740 proposes using two-stage cooling so as to achieve both hole expansion and other workability and material corrosion resistance, it does not completely make up for the deterioration in the hole expansibility due to the addition of Cu and P. Due to the orientation toward further reduction of weight of automobiles, the increasing complexity of parts, etc., a further higher hole expansibility is being sought and a higher workability and higher strength unable to be achieved in the prior art are being demanded in steel sheet excellent in material corrosion resistance.

[0003]

[PROBLEM TO BE SOLVED BY THE INVENTION] The present invention relates to hot rolled steel sheet of the 590N/mm² class or more and attempts to provide high strength hot rolled steel sheet excellent in material corrosion resistance achieving both excellent hole expansibility and ductility.

[0004]

[MEANS FOR SOLVING THE PROBLEMS] To solve the problems of the present invention, various experiments and studies have been performed. As a result, it is well known that the state of cracks in punched holes is important for improvement of the hole expansibility. The inventors engaged in in-depth studies and as a result discovered that by adding Mg, it is possible to make the cracks formed at the cross-section of punched holes finer and more uniform. Further, by making oxides present in the steel sheet and composite precipitates of (Nb, Ti)N having these as nuclei uniformly and finely disperse and precipitate, it is believed that it is possible to cause the formation of fine voids at the time of punching and thereby ease the concentration of stress and believed possible to suppress the occurrence of coarse cracks and improve the hole expansibility. Due to this, they came up with the present invention. Up to now, as proposals utilizing oxides obtained by addition of Mg, for example, the proposal of Japanese Patent Publication (A) No. 11-323488 relating to improvement of in-plane anisotropy is directed to use of Mg oxides for suppression of the preferential nucleation and growth in the planar direction at the time of recrystallization. The proposal of Japanese Patent

Publication (A) No. 11-236645 relating to the toughness of the weld zone aims at using Mg composite oxides to suppress the growth of γ grains of the HAZ part at the time of superlarge heat input welding. These utilize the pinning effect by fine oxides. Unlike the utilization of the fine voids formed by inclusions at the time of punching of the present invention, it is not certain that the hole expansibility is improved at steel sheet aimed at these. The gist of the present invention is as follows.

[0005] 1) A low corrosion speed high strength hot rolled steel sheet excellent in hole expansibility and ductility characterized by containing, by wt%, C: 0.01% to 0.20%, Si: 0.05% to 1.5%, Mn: 0.5% to 2.5%, P: 0.03% to 0.2%, S: 0.009% or less, Cu: 0.1% to 1.0%, Ni: 0.1% to 1.0%, N: 0.010% or less, Mg: 0.0005% to 0.01%, Al: 0.002% to 0.07% and one or both of Ti: 0.003% to 0.25% and Nb: 0.003% to 0.04%,

having a balance of iron and unavoidable impurities, making the steel structure containing MgO having a particle size of 0.005 μm to 5.0 μm in range or composite oxides of one or more of Al_2O_3 , SiO_2 , MnO , and Ti_2O_3 including MgO in an amount of 1.0×10^3 to 1.0×10^7 particles per square mm mainly a ferrite structure and making the remainder a bainite structure.

[0006] 2) A low corrosion speed high strength hot rolled steel sheet excellent in hole expansibility and ductility characterized by containing, by wt%, C: 0.01% or more, 0.20% or less, Si: 0.05% to 1.5%, Mn: 0.5% to 2.5%, P: 0.03% to 0.2%, S: 0.009% or less, Cu: 0.1% to 1.0%, Ni: 0.1% to 1.0%, N: 0.010% or less, Mg: 0.0005% to 0.01%,

Al: 0.002% to 0.07%, and one or both of Ti: 0.003% to 0.25% and Nb: 0.003% to 0.04%,

having a balance of iron and unavoidable impurities, and making a steel structure containing MgO having a particle size of 0.005 μm to 5.0 μm or composite oxides of one or more of Al_2O_3 , SiO_2 , MnO , and Ti_2O_3 including MgO and precipitates comprised of composite precipitates having these as nuclei around which (Nb, Ti)N is formed and having a size of 0.05 μm to 5.0 μm in range in an amount of 1.0×10^3 to 1.0×10^7 particles per square mm mainly a ferrite structure and making the remainder a bainite structure.

[0007] 3) A low corrosion speed high strength hot rolled steel sheet excellent in hole expansibility and ductility characterized by containing, by wt%, C: 0.01% to 0.20%, Si: 0.05% to 1.5%, Mn: 0.5% to 2.5%, P: 0.03% to 0.2%, S: 0.009% or less, Cu: 0.1% to 1.0%, Ni: 0.1% to 1.0%, N: 0.010% or less, Mg: 0.0005% to 0.01%, Al: 0.002% to 0.07%, and

one or both of Ti: 0.003% to 0.25% and Nb: 0.003% to 0.04%, having a balance of iron and unavoidable impurities, further containing one or both of Ca: 0.0005% to 0.0100% and REM elements in total: 0.0005% to 0.0100%, having a balance of iron and unavoidable impurities, and making a steel structure containing MgO having a particle size of 0.005 μm to 5.0 μm or composite oxides of one or more of Al_2O_3 , SiO_2 , MnO , and Ti_2O_3 including MgO in an amount of 1.0×10^3 to 1.0×10^7 particles per square mm mainly a ferrite structure and making the remainder a bainite structure.

[0008] 4) A low corrosion speed high strength hot rolled steel sheet excellent in hole expansibility and ductility characterized by containing, by wt%, C: 0.01% to 0.20%, Si:

0.05% to 1.5%, Mn: 0.5% to 2.5%, P: 0.03% to 0.2%, S: 0.009% or less, Cu: 0.1% to 1.0%, Ni: 0.1% to 1.0%, N: 0.010% or less, Mg: 0.0005% to 0.01%, Al: 0.002% to 0.07%, and one or both of Ti: 0.003% to 0.25% and Nb: 0.003% to 0.04%, having a balance of iron and unavoidable impurities, further containing one or both of Ca: 0.0005% to 0.0100% and REM elements in total: 0.0005% to 0.0100%, having a balance of iron and unavoidable impurities, making the steel structure containing MgO having a particle size of 0.005 μm to 5.0 μm or composite oxides of one or more of Al_2O_3 , SiO_2 , MnO , and Ti_2O_3 including MgO and precipitates comprised of composite precipitates having these as nuclei around which (Nb, Ti)N is formed and having a size of 0.05 μm to 5.0 μm in range in an amount of 1.0×10^3 to 1.0×10^7 particles per square mm mainly a ferrite structure and making the remainder a bainite structure.

[0009] 5) A method of production of low corrosion speed high strength hot rolled steel sheet excellent in hole expansibility and ductility characterized by rolling steel described in claim 1 or claim 2 or claim 3 or claim 4 by a rolling end temperature of the Ar_3 transformation point or more, then cooling by a 20°C/sec or more cooling speed, and taking up the sheet at 350°C to 600°C so as to make the steel structure mainly a ferrite structure and make the remainder a bainite structure.

[0010] 6) A method of production of low corrosion speed high strength hot rolled steel sheet excellent in hole expansibility and ductility characterized by rolling steel described in claim 1 or claim 2 or claim 3 or claim 4 by a rolling end temperature of the Ar_3 transformation point or more, then cooling by a 20°C/sec or more cooling speed down

to 650°C to 700°C, air cooling at that temperature for 15 seconds or less, then again cooling and coiling at 350°C to 600°C so as to make the steel structure mainly a ferrite structure and make the remainder a bainite structure.

[0011] 7) A method of production of low corrosion speed high strength hot rolled steel sheet excellent in hole expansibility and ductility characterized by adding Si and Mn, then adding Ti, then adding Mg and Al in the steel described in claim 1 or claim 2 or claim 3 or claim 4 and at the step of adjusting the ingredients at a melting stage of the method of production of steel described in claim 5 or claim 6.

[0012] 8) A method of production of low corrosion speed high strength hot rolled steel sheet excellent in hole expansibility and ductility as set forth in claim 5 or claim 6 or claim 7 characterized by using an Mg alloy comprised of one or more of Si, Ni, Cu, Al, and REM (rare earth metal) as a dilute solvent metal of Mg.

[0013] 9) A method of production of low corrosion speed high strength hot rolled steel sheet excellent in hole expansibility and ductility as set forth in claim 8 characterized in that an Mg concentration in the Mg alloy is 1% to less than 10%.

[0014] 10) A low corrosion speed high strength hot rolled steel sheet excellent in hole expansibility and ductility as set forth in claims 7 to 9 characterized in that a sum of concentrations of Fe, Mn, and Cr in the Mg alloy is less than 10% and a method of production of the same.

[0015]

[EMBODIMENTS OF THE INVENTION] The present invention suppresses coarse cracks at the punched holes for

improvement of the hole expansibility. For this, it adds Mg, causes oxides to uniformly and finely precipitate, and thereby suppresses the occurrence of coarse cracks at the time of punching and improves the hole expansibility. Below, the individual constituent requirements of the present invention will be explained in detail.

[0016] First, the reasons for limitation of the ingredients of the present invention will be explained. C is an element having an effect on the workability of the steel. If the content becomes greater, the workability is degraded. In particular, if over 0.20%, carbides (pearlite and cementite) harmful to the hole expansibility are formed, so the amount is 0.20% or less. However, preferably, 0.15% or less is desirable. Further, from the viewpoint of securing the strength, 0.01% or more is necessary.

[0017] Si is preferably low to reduce the corrosion speed, but is an element important for suppressing the formation of harmful carbides and obtaining a composite structure of mainly ferrite structure and a balance of bainite. To secure the lowest limit of this effect, addition of 0.05 or more is necessary. On the other hand, if the amount of addition increases, the chemical convertibility falls and also the point weldability deteriorates, so 1.5% is made the upper limit.

[0018] Mn is an element necessary for securing the strength. Addition of a minimum of 0.50% is necessary. However, if adding a large amount, microsegregation and macrosegregation easily occur. These cause deterioration of the hole expansibility. Due to this, 2.50% is made the upper limit.

[0019] P is an element having the most effect on the

corrosion resistance. It is particularly effective for perforation corrosion resistance. Inclusion of 0.03% or more is necessary. P has been considered poor in weldability, but under conditions of low C and low N, the detrimental effect of P on weldability can be eliminated. However, if the amount of addition is large, the secondary workability deteriorates, cracks form at the time of pressing, and breakage occurs with just a slight force after press formation. Due to this, the amount is made 0.20% or less.

[0020] S forms MnS and other nonmetallic inclusions and degrades the ductility and hole expansibility, so is preferably not present in the steel. The smaller the amount of addition the better, so the amount is made 0.009% or less. However, if 0.005% or less, this effect remarkably appears, so 0.005% or less is preferable.

[0021] Cu is an element necessary for increasing the density of the stable rust together with P. The effect appears if 0.10% or more. Further, if over 1.0%, the effect of addition becomes saturated and peeling or other defects easily occur, so 1.0% is made the upper limit.

[0022] Ni is effective for prevention of the occurrence of Cu peeling. Addition of an amount equal to the Cu is preferable. Further, it is also effective for the improvement of the corrosion resistance. For this reason, 0.1% or more is added. However, even if added in a large amount, the effect becomes saturated. Not only this, an increase in cost is incurred, so the upper limit is made 1.0%.

[0023] N is preferably small in amount to secure the workability. If over 0.010%, the workability deteriorates,

so the amount is made 0.010% or less. 0.005% or less is preferable.

[0024] Mg is one of the most important additive elements in the present invention. Mg, upon addition, bonds with oxygen to form oxides, but it was discovered that by making the MgO or composite oxides of Al_2O_3 , SiO_2 , MnO , and Ti_2O_3 including MgO formed at this time finer, the individual oxide particles are smaller in size and the particles are more uniformly dispersed compared with conventional steel in which Mg is not added. Finely dispersed in the steel, these oxides, while not certain, are believed to be effective for formation of fine voids at the time of punching and suppression of stress concentration so as to suppress the formation of coarse cracks and are believed to be effective for the improvement of hole expansibility. However, if less than 0.0005%, the effect is insufficient. On the other hand, with addition of over 0.01%, not only is improvement relative to the amount of addition saturated, but also conversely the cleanliness of the steel is degraded and the hole expansibility and ductility are degraded, so the upper limit is made 0.01%.

[0025] Al is one of the most important additive elements in the present invention. Al easily forms $MgAl_2O_4$ composite oxides having a spinel structure when Mg is added. $MgAl_2O_4$ composite oxides are a form of the finest oxides among composite oxides of Al_2O_3 , SiO_2 , MnO , and Ti_2O_3 including MgO and are believed to be effective for making the state of dispersion of the oxides more uniform and finer. For this reason, at the time of punching, fine voids are formed. These suppress the stress concentration and thereby are believed to have the effect of suppressing the formation of

coarse cracks and are believed to have the effect of improvement of the hole expansibility. Due to this, 0.002% or more is added. However, if the amount of addition increases, the effect of addition of Mg is impaired, so the amount is made 0.07% or less. In particular, to raise the ratio of the MgAl composite oxides among the composite oxides in the oxides and efficiently achieve greater fineness of oxides, the amount of addition is preferably 0.02% to 0.07%.

[0026] Ti and Nb are some of the most important additive elements in the present invention. Ti and Nb precipitate about nuclei of finely and uniformly precipitating oxides, in particular composite oxides mainly comprised of small MgO or MgAl₂O₄. By precipitating on these oxides, they act to increase the size of the precipitates and thereby assist the formation of fine voids of MgO or MgAl₂O₄. Further, this is also effective for increasing the strength. To effectively bring out these effects, addition of at least 0.003% of both Nb and Ti is necessary. Addition of 0.01% or more is preferable. However, if addition of these becomes excessive, the precipitation strengthening causes the ductility to deteriorate, so the upper limit of Ti is made 0.25% or less and of Nb is made 0.04% or less. These elements are effective even if added alone and are effective even if added compositely.

[0027] Ca controls the shape of sulfide-based inclusions and is effective for improvement of the hole expansibility. To effectively bring this out, addition of 0.0005% or more is necessary. On the other hand, addition of a large amount conversely degrades the cleanliness of the steel, so impairs the hole expansibility and ductility. Due to this,

the upper limit is made 0.0100%. REM elements have similar effects to Ca. That is, a REM controls the shape of sulfide-based inclusions and is effective for improvement of the hole expansibility. To effectively bring this out, addition of a total of REM elements of 0.0005% or more is necessary. On the other hand, addition of a large amount conversely degrades the cleanliness of the steel, so impairs the hole expansibility and ductility. Further, the production costs are also high, so the upper limit was made 0.0100%.

[0028] As the oxides, MgO or composite oxides of two or more of Al_2O_3 , SiO_2 , MnO , and Ti_2O_3 , including MgO may also be used. The inventors engaged in in-depth studies and as a result learned that among the composite oxides, MgO and MgAl_2O_4 are effective in forming fine cracks in a state different from other composite oxides, these are all effects obtained by addition of Mg, and the synergistic effect causes an improvement in the hole expansibility.

[0029] MgO and MgAl_2O_4 mainly cause precipitation of (Nb, Ti)N around them and thereby have the effect of forming fine voids. MgO and MgAl_2O_4 are believed to contribute to this as nuclei for precipitation uniformly dispersed. On the other hand, fine composite oxides other than MgO and MgAl_2O_4 precipitate finely dispersed due to the formation of composite oxides with MgO and have the effect of formation of fine voids as oxides alone without causing precipitation of (Nb, Ti)N around them. In particular, the fine composite oxides other than MgO and MgAl_2O_4 are almost all composite oxides mainly comprised of MgO, Al_2O_3 , and SiO_2 . At this time, the ratio of MgO, Al_2O_3 , and SiO_2 oxides in the whole is 90% or more.

[0030] If the particle size of oxides is less than 0.005 μm , there is little precipitation of (Nb, Ti)N around them. On the other hand, it is difficult for this size of oxides to become nuclei for formation of fine cracks without coprecipitation of (Nb, Ti)N. The effect of formation of fine voids becomes difficult to obtain, so the size is made 0.005 μm or more. Conversely, if over 5.0 μm , securing the number of particles is difficult. Further, coarse precipitates invite deterioration in the ductility, so the size is made 5.0 μm or less.

[0031] If the oxides and composite precipitates are small in size, they do not form starting points for fine voids, so cannot exhibit the desired effect. Therefore, the size is made 0.05 μm or more. On the other hand, if over 5.0 μm , securing the number of particles is difficult. These assist the formation of coarse cracks and reduce the hole expansibility, so the size is made 5.0 μm or less.

[0032] If the precipitate density, that is, number, is low, the fine voids formed at the time of punching become insufficient and the effect of suppression of formation of coarse cracks may not be obtained. To obtain this effect, 1.0×10^3 or more per square mm is necessary. On the other hand, if the number becomes large, the effect becomes saturated and conversely the ductility is degraded, so the density is made 1.0×10^7 or less. However, from the balance between the saturation of this effect and the ductility, 1.0×10^6 or less is preferable.

[0033] Further, as the means for improving the hole expansibility, in addition to the properties of the punched hole, improving the local ductility of the base material is

effective. To improve the local ductility of the base material, making the structure uniform is effective, but in single phase steel, at the strength aimed at by the present invention, the deterioration of the ductility is large and the targeted properties cannot be obtained. For this reason, the structure of the steel is made a composite structure of mainly a ferrite structure. However, if the ratio of the ferrite structure is high and the result becomes a single phase steel, a drop in the ductility or strength is caused. Further, when the ratio is low, the effect of the second phase with the low elongation is felt and the ductility falls. For this reason, the ratio of the ferrite structure is preferably 50% to 95%. Further, when the remaining structure is a martensite, coarse cementite, or pearlite structure, cracks form at the interface between the ferrite structure and these structures and the local deformation ability falls. On the other hand, a bainite structure is a structure comprised of a ferrite structure in which fine cementite is dispersed. To prevent a drop in the local ductility of the base material, the structure of the steel is made mainly a ferrite structure and the remainder a bainite structure.

[0034] The state of dispersion of inclusions prescribed in the present invention is for example quantitatively measured by the following method. An extraction replica sample is prepared from any location of the base material steel sheet. This is observed using said transmission electron microscope (TEM) at a power of 5000X to 20000X over an area of at least $5000 \mu\text{m}^2$. The number of composite inclusions covered is measured and converted to a number per unit time. At this time, the oxides and the $(\text{Nb}, \text{Ti})\text{N}$

are identified by analysis of the composition by an energy dispersion type X-ray spectrometer (EDS) attached to the TEM and by analysis of the crystalline structure of an electron beam diffraction image by the TEM. When such identification is bothersome for all composite inclusions measured, for simplification, the following procedure is used. First, the number of inclusions of the size covered is measured for each shape and size by the above guidelines. Among these, 10 or more inclusions are identified for all of the different shapes and sizes by the above guidelines, and the ratio of the oxides and (Nb, Ti)N is calculated. Further, this ratio is multiplied with the number of inclusions measured. If the carbides in the steel interfere with the above TEM observation, it is possible to use heat treatment to make the carbides agglomerate and grow or dissolve them to facilitate the observation of the composite inclusions covered.

[0035] Next, the method of production will be explained. The final rolling end temperature has to be made the Ar₃ transformation point or more so as to inhibit the formation of ferrite and improve the hole expansibility. However, if too high a temperature, the coarsening of the structure results in the reduction of the strength and a drop in the ductility, so the temperature is preferably made 950°C or less. The cooling speed has to be 20°C/s or more to suppress the formation of carbides harmful to hole expansibility and obtain a high hole expansion ratio. If the cooling temperature is less than 350°C, hard martensite harmful to the hole expansibility is formed, so the temperature is made 350°C or more. On the other hand, if the upper limit becomes over 600°C, pearlite and cementite harmful to the

hole expansibility are formed, so the limit is made 600°C or less.

[0036] The air cooling during continuous cooling is effective for increasing the ratio of the ferrite phase and improving the ductility. However, if pearlite is formed due to the air cooling temperature and the air cooling time, conversely the ductility falls and, not only that, the hole expansibility remarkably drops. If the air cooling temperature is less than 650°C, pearlite harmful to hole expansibility is formed early, so the temperature is made 650°C or more. On the other hand, if over 700°C, the ferrite formation is slow and the effect of air cooling is difficult to obtain and, not only that, pearlite is more easily formed during the subsequent cooling, so the temperature is made 700°C or less. If air cooling for over 15 seconds, not only is the increase of the ferrite phase saturated, but also a load is placed on control of the cooling speed and cooling temperature. For this reason, the air cooling time is made 15 seconds or less.

[0037] Next, the order of addition of ingredients at the stage of adjustment in the production process was studied by the inventors. As a result, when adding Si and Mn, then adding Ti, then adding Mg and Al, the yield of Mg in the molten steel increases and the oxides become finer in size and therefore the state of dispersion of the size of oxides demanded in the present invention becomes easier to stably obtain, so this is more preferable. Mg has a high volatility in molten steel. If charging it into molten steel in the form of Mg pure metal, the yield of Mg is extremely low. For this reason, Mg is charged into the molten steel in the form of an alloy with a dilute solvent

metal. At this time, the inventors engaged in in-depth studies and as a result discovered that when using an Mg alloy comprised of one or more of Si, Ni, Cu, Al, and an REM (rare earth metal) as a dilute solvent metal of Mg, the amount of Mg remaining in the steel is improved. With an alloy mainly comprised of another metal, this effect could not be obtained. As the dilute solvent metal of Mg, it is preferable to select Si, Ni, Cu, Al, or an REM (rare earth metal) having interaction of interatomic forces with Mg. Among these, it is preferable to use an Mg alloy comprising one or more of these to charge Mg in the molten steel. Here, the range of the "rare earth metals", as, for example, described in the Physiochemical Dictionary, Edition 5, page 309, Iwanami Shoten, 1998, is the general name for the Sc, Y, and lanthanoids (La of atomic number 57 to Lu of 71) belonging to Group III of the Periodic Table. [0038] Further, the inventors engaged in in-depth studies and as a result discovered that if the concentration of Mg in the Mg alloy is less than 10%, the Mg yield remarkably increases and a suitable size and number of oxides are easily stably obtained. On the other hand, if less than 1%, at the time of addition of Mg alloy, the dilute solvent metal excessively dissolves in the steel, so adjustment of the ingredients becomes difficult. Therefore, the concentration of Mg in the alloy is preferably made 1% to less than 10%. The inventors discovered that when the sum of the concentrations of the Fe, Mn, and Cr in the Mg alloy is less than 10%, the Mg yield remarkably increases and further a suitable size and number of oxides are easily stably obtained. This is interpreted as being due to the action of interatomic repulsion between the Mg formed when

the Mg alloy dissolves in the molten steel and these elements. Therefore, the sum of the concentrations of the Fe, Mn, and Cr in the Mg alloy is preferably less than 10%. Even if the steel sheet of the present invention is hot rolled, then plated by annealing as with hot dip galvanization, the effect of the present invention will not be impaired. Further, even if hot rolled, then electroplated and given an organic composite film, the effect will not be impaired.

[0039]

[EXAMPLES] Next, the present invention will be explained based on examples. To produce steel of the steel ingredients shown in Table 1, pig iron 270t was decarburized by a converter to the target C concentration, then the molten steel was transferred to a ladle and deoxidized and adjusted in alloy by the CAS method (described in the Iron and Steel Institute of Japan ed., Hiroyuki Kajioka, Ladle Refining Method, page 104, Chijinshokan, issued in 1997). Examples of deoxidizing the molten steel by adding Si and Mn, then adding Ti, then adding Mg and Al in that order and other examples are shown in Table 1. Here, as the Si, Mn, and Ti material, FeSi, FeMn, and FeTi was used. Further, examples of using Mg alloys using one or more of Si, Ni, Cu, Al, and an REM (rare earth metal) as the dilute solvent metal for Mg and Al, having a concentration of Mg in the Mg alloy of 1% to less than 10%, and having concentrations of Fe, Mn, and Cr in the Mg alloy of less than 10% and examples of using other alloys are also shown in Table 1. After deoxidation, the necessary elements were adjusted to target ranges of the concentrations of ingredients, then immediately a

continuous casting machine was used to produce slabs of a thickness of 250 mm and a width of 1300 mm. These steels were heated to 1200°C or more in a heating furnace and rolled and cooled under the hot rolling conditions shown in Table 2 to obtain hot rolled steel sheets of a thickness of 2.6 to 3.2 mm.

[0040] On the other hand, Table 3 shows examples of use of an Mg alloy using one or more of Si, Ni, Cu, Al, and an REM (rare earth metal) as a dilute solvent metal for addition of Mg, having a concentration of Mg in the Mg alloy of 1% to less than 10%, and having a sum of concentrations of Fe, Mn, and Cr in the Mg alloy of less than 10% and, at the stage of adjusting the ingredients in the process of production, adding Si and Mn, then adding Ti, then adding Mg and Al for deoxidation. It shows the changes in ingredients. The notations D to Y show steels in accordance with the present invention, while the other notations show steels with amounts of addition of C, Si, Mn, S, Al, Mg, Nb, or Ti outside the scope of the present invention. These steels were heated to 1200°C or more in a heating furnace and hot rolled and cooled under the hot rolling conditions shown in Table 4 to obtain hot rolled steel sheets of a thickness of 2.6 to 3.2 mm. Further, extraction replica samples were prepared from the steel sheet base materials and measured by the above-mentioned methods for the size and numbers of oxides and (Ti, Nb)N composite oxides using these as nuclei which were then converted to a number of per unit. This is shown in Tables 1 and 3.

[0041] JIS No. 5 pieces of the hot rolled steel sheet obtained in this way were subjected to tensile tests and hole expansion tests and observed for structure. The hole

expansibility (λ) was evaluated by pushing wider a diameter 12 mm punched hole by a 60° conical punch and determining $\lambda = (d-d_0)/d_0 \times 100$ from the hole diameter (d) at the time when the crack passed through the sheet thickness and the initial hole diameter (d_0 : 12 mm). The TS, El, and λ of the test pieces are shown in Tables 2 and 4. FIG. 1 shows the relationship between the strength and elongation, while FIG. 2 shows the relationship between the strength and hole expansion ratio. It is learned that the invention steels have a hole expansion ratio higher than Comparative Steel 1 and both a hole expansion ratio and elongation higher than Comparative Steel 2. In this way, it is learned that the steel sheets of the present invention are excellent in both the hole expansion ratio and ductility.

[0042] Further, the corrosion resistance was evaluated by treating the steel sheet by phosphate treatment (BTL3080 made by Parker Japan), then coating it by cationic electrodeposition (Powertop D-30 made by Nippon Paint, coated to 20 μm), cross-cutting the sheet to the base material, then running an acceleration test consisting of a cycle of salt water spraying at 5°C/6 hours - drying at 70°C/RH60%/4 hours - wetting at 49°C/RH95%/4 hours - and cooling at 20°C/4 hours for 80 cycles, and determining the depth of corrosion of the cross-cut parts. The results are shown in Tables 2 and 4. Due to this, V and W having amounts of addition of Cu and P outside the scope of the present invention are inferior in corrosion resistance compared with the invention steels. It is learned that the invention steels are superior in corrosion resistance as well. Note that here the alloy was charged by the CAS

method, but the invention is not particularly limited to this. We add that the vacuum tank alloy addition method of an RH degassing apparatus, molten steel ladle wire addition method, powder injection method, or other known method may also be used without problem.

[Table 1]

Steel	C	Si	Mn	P	S	N	Cu	Ni	Mg	Al	Nb	Ti	Ca	Order of addition	Dilute solvent metal	Mg conc.	Fe, Mn, Cr conc.	No. of precipitates/um ²	Ar3 °C	Remarks
A1	0.049	0.100	1.200	0.060	0.003	0.002	0.102	0.210	0.009	0.004	0.320	0.170	-	Si-Mn-Ti-Mg-A	Si	7	8	746	Inv. ex.	
A2	0.059	0.100	1.210	0.050	0.002	0.001	0.100	0.210	0.009	0.005	0.310	0.170	-	Si-Mn-Ti-Mg-A	Si	7	7	794	Inv. ex.	
A3	0.050	0.100	1.210	0.050	0.002	0.001	0.100	0.210	0.009	0.005	0.310	0.170	-	Si-Mn-Ti-Mg-A	Si	7	7	793	Inv. ex.	
A4	0.039	0.050	1.190	0.050	0.001	0.001	0.092	0.200	0.010	0.005	0.311	0.171	-	Si-Mn-Ti-Mg-A	Si	8	8	796	Comp. ex.	
A5	0.043	0.050	1.200	0.050	0.003	0.002	0.100	0.210	0.009	0.004	0.311	0.171	-	Si-Mn-Ti-Mg-A	Si	12	12	795	Comp. ex.	
A6	0.043	0.050	1.200	0.050	0.003	0.002	0.100	0.210	0.009	0.004	0.311	0.171	-	Si-Mn-Ti-Mg-A	Si	5	5	795	Comp. ex.	
A7	0.044	0.050	1.200	0.050	0.003	0.002	0.100	0.210	0.009	0.004	0.311	0.171	-	Si-Mn-Ti-Mg-A	Fe	5	5	794	Comp. ex.	
A8	0.044	0.050	1.200	0.050	0.003	0.002	0.100	0.210	0.009	0.004	0.311	0.171	-	Si-Mn-Ti-Mg-A	Si	7	7	795	Comp. ex.	
B1	0.039	0.050	1.000	0.060	0.001	0.001	0.093	0.201	0.162	0.004	0.314	0.360	0.003	Si-Mn-Ti-Mg-A	Si	8	8	793	Inv. ex.	
D2	0.028	0.050	1.000	0.060	0.001	0.001	0.092	0.200	0.160	0.003	0.313	0.362	0.003	Si-Mn-Ti-Mg-A	Si	9	9	794	Inv. ex.	
B3	0.028	0.050	1.000	0.060	0.001	0.001	0.093	0.201	0.161	0.004	0.313	0.362	0.003	Si-Mn-Ti-Mg-A	Si	9	9	794	Inv. ex.	
B4	0.029	0.110	1.000	0.061	0.003	0.002	0.100	0.169	0.093	0.014	0.311	0.360	0.003	Si-Mn-Ti-Mg-A	Si	7	7	792	Inv. ex.	
B5	0.028	0.100	1.000	0.060	0.002	0.002	0.100	0.169	0.093	0.013	0.310	0.360	0.003	Si-Mn-Ti-Mg-A	Si	7	7	792	Inv. ex.	
B6	0.029	0.110	1.000	0.060	0.002	0.001	0.100	0.169	0.093	0.014	0.310	0.360	0.003	Si-Mn-Ti-Mg-A	Al	6	6	793	Inv. ex.	
B7	0.028	0.100	1.000	0.060	0.002	0.001	0.100	0.169	0.093	0.015	0.310	0.360	0.003	Si-Mn-Ti-Mg-A	FeMn	9	9	794	Inv. ex.	
B8	0.028	0.100	1.000	0.060	0.002	0.001	0.100	0.169	0.093	0.016	0.310	0.360	0.003	Si-Mn-Ti-Mg-A	Si	12	12	794	Comp. ex.	
B9	0.028	0.100	1.000	0.060	0.002	0.001	0.100	0.169	0.093	0.016	0.310	0.360	0.003	Si-Mn-Ti-Mg-A	Fe, Mn	6	6	795	Comp. ex.	
B10	0.028	0.100	1.000	0.060	0.002	0.001	0.100	0.169	0.093	0.016	0.310	0.360	0.003	Si-Mn-Ti-Mg-A	Fe, Cr	7	7	795	Comp. ex.	
B11	0.028	0.100	1.000	0.060	0.002	0.001	0.100	0.169	0.093	0.016	0.310	0.360	0.003	Si-Mn-Ti-Mg-A	Si	7	7	794	Comp. ex.	
B12	0.028	0.100	1.000	0.060	0.002	0.001	0.100	0.169	0.093	0.016	0.310	0.360	0.003	Si-Mn-Ti-Mg-A	Al	6	6	794	Comp. ex.	
B13	0.028	0.100	1.000	0.060	0.002	0.001	0.100	0.169	0.093	0.016	0.310	0.360	0.003	Si-Mn-Ti-Mg-A	Si	7	7	794	Comp. ex.	
B14	0.028	0.100	1.000	0.060	0.002	0.001	0.100	0.169	0.093	0.016	0.310	0.360	0.003	Si-Mn-Ti-Mg-A	Fe, Mn	6	6	795	Comp. ex.	
B15	0.028	0.100	1.000	0.060	0.002	0.001	0.100	0.169	0.093	0.016	0.310	0.360	0.003	Si-Mn-Ti-Mg-A	Fe, Cr	7	7	795	Comp. ex.	
B16	0.028	0.100	1.000	0.060	0.002	0.001	0.100	0.169	0.093	0.016	0.310	0.360	0.003	Si-Mn-Ti-Mg-A	Si	4	4	793	Inv. ex.	
B17	0.028	0.100	1.000	0.060	0.002	0.001	0.100	0.169	0.093	0.016	0.310	0.360	0.003	Si-Mn-Ti-Mg-A	Al	6	6	794	Inv. ex.	
B18	0.028	0.100	1.000	0.060	0.002	0.001	0.100	0.169	0.093	0.016	0.310	0.360	0.003	Si-Mn-Ti-Mg-A	FeMn	5	5	794	Inv. ex.	
B19	0.028	0.100	1.000	0.060	0.002	0.001	0.100	0.169	0.093	0.016	0.310	0.360	0.003	Si-Mn-Ti-Mg-A	Fe, Mn	6	6	795	Comp. ex.	
B20	0.028	0.100	1.000	0.060	0.002	0.001	0.100	0.169	0.093	0.016	0.310	0.360	0.003	Si-Mn-Ti-Mg-A	Fe, Cr	7	7	795	Comp. ex.	
B21	0.028	0.100	1.000	0.060	0.002	0.001	0.100	0.169	0.093	0.016	0.310	0.360	0.003	Si-Mn-Ti-Mg-A	Si	4	4	793	Inv. ex.	
B22	0.028	0.100	1.000	0.060	0.002	0.001	0.100	0.169	0.093	0.016	0.310	0.360	0.003	Si-Mn-Ti-Mg-A	Al	6	6	794	Inv. ex.	
B23	0.028	0.100	1.000	0.060	0.002	0.001	0.100	0.169	0.093	0.016	0.310	0.360	0.003	Si-Mn-Ti-Mg-A	FeMn	9	9	794	Inv. ex.	
B24	0.028	0.100	1.000	0.060	0.002	0.001	0.100	0.169	0.093	0.016	0.310	0.360	0.003	Si-Mn-Ti-Mg-A	Fe, Mn	7	7	794	Comp. ex.	
B25	0.028	0.100	1.000	0.060	0.002	0.001	0.100	0.169	0.093	0.016	0.310	0.360	0.003	Si-Mn-Ti-Mg-A	Fe, Cr	7	7	794	Comp. ex.	
B26	0.030	0.100	1.510	0.063	0.003	0.003	0.180	0.180	0.004	0.004	0.310	0.310	0.003	Si-Al-Si-Mn-Ti	Si	6	6	300-301	379	Comp. ex.

* Provided, however, that Ar3 = 300-301°C for C1-C20 and 379°C for C21-C26.

[Table 2]

Steel	Final temp., °C	Cooling speed, °C/s	Air cooling start temp., °C	Air cooling time, s	Cooling temp., °C	Tensile strength, N/mm ²	Elonga- tion %	Hole expansion %	Corrosion resistance judgment	Corrosion resistance judgment	Remarks
A1	860	60	680	3	510	707	25	95	0.40	0	Inv. ex.
A2	875	50	670	4	550	708	24	100	0.50	0	Inv. ex.
A3	860	60	—	—	500	716	23	100	0.49	0	Inv. ex.
A4	870	60	670	3	510	707	24	75	0.45	0	Comp. ex.
A5	870	60	670	3	490	706	25	70	0.46	0	Comp. ex.
A6	860	60	670	4	500	708	25	70	0.42	0	Comp. ex.
A7	860	60	—	—	600	708	18	80	0.43	0	Comp. ex.
B1	880	60	660	4	500	600	29	115	0.48	0	Inv. ex.
B2	870	60	670	8	550	602	26	120	0.49	0	Inv. ex.
B3	880	30	670	3	450	601	28	115	0.44	0	Inv. ex.
B4	870	60	—	—	550	603	26	125	0.42	0	Inv. ex.
B5	870	70	—	—	490	601	27	125	0.47	0	Inv. ex.
B6	860	50	—	—	440	603	27	120	0.44	0	Inv. ex.
B7	860	60	670	7	550	602	28	80	0.41	0	Comp. ex.
B8	870	60	670	8	550	602	28	85	0.43	0	Comp. ex.
B9	870	50	—	—	480	602	27	80	0.41	0	Comp. ex.
B10	875	50	—	—	500	602	23	85	0.41	0	Comp. ex.
B11	860	50	—	—	480	604	22	90	0.40	0	Comp. ex.
C1	860	50	680	3	550	778	23	90	0.42	0	Inv. ex.
C2	860	50	670	8	500	780	22	90	0.42	0	Inv. ex.
C3	850	60	670	4	550	781	22	85	0.46	0	Inv. ex.
C4	880	40	—	—	450	778	21	100	0.47	0	Inv. ex.
C5	870	50	—	—	500	780	21	95	0.46	0	Inv. ex.
C6	870	50	680	4	540	779	23	100	0.42	0	Inv. ex.
C7	870	50	670	3	550	776	22	60	0.45	0	Inv. ex.
C8	870	60	680	4	550	777	18	55	0.47	0	Comp. ex.

The asterisked conditions in the table are outside the scope of the present invention.

The corrosion depth was judged 0 (good) when the corrosion depth was less than 0.55 mm and was judged x (poor) when it was 0.55 mm or more.

Steel	C	Si	Mn	P	S	N	Cu	Ni	Mg	Al	Nb	Ti	Ca	REM	No. of precipi- tates/mm ²	No. of Ar3 °C	Remarks	
D	0.03	0.20	1.00	0.060	0.003	0.002	0.20	0.10	0.0022	0.0041	0.015	-	-	-	14F-44	837	Inv. ex.	
E	0.01	0.10	1.10	0.100	0.005	0.002	0.40	0.20	0.0032	0.0030	0.005	-	0.0026	-	1.2E-04	847	Inv. ex.	
F	0.04	0.60	1.60	0.060	0.005	0.002	0.20	0.18	0.0037	0.003	0.040	0.130	0.0020	-	1.1E-04	804	Inv. ex.	
G	0.04	0.05	1.40	0.060	0.002	0.002	0.30	0.30	0.0034	0.002	0.030	-	-	-	1.5E-04	802	Inv. ex.	
H	0.03	0.90	2.50	0.060	0.003	0.002	0.20	0.16	0.0100	0.045	-	0.120	0.0020	-	1.1E-07	780	Inv. ex.	
I	0.04	0.06	1.50	0.055	0.005	0.002	0.20	0.10	0.0011	0.0005	0.030	0.070	0.0080	-	3.8E-03	705	Inv. ex.	
J	0.04	1.20	1.40	0.050	0.013	0.002	0.20	0.18	0.0047	0.005	0.040	0.070	0.0030	-	8.2E+03	633	Inv. ex.	
K	0.04	0.70	2.00	0.055	0.002	0.005	0.20	0.18	0.0047	0.005	0.040	0.070	0.0030	-	8.0E+03	780	Inv. ex.	
L	0.04	0.16	1.80	0.055	0.002	0.003	0.40	0.18	0.0025	0.0025	0.030	-	0.0030	-	9.0E+04	778	Inv. ex.	
M	0.04	1.50	0.50	0.200	0.002	0.002	0.30	0.30	0.0025	0.0033	0.025	-	0.0025	-	2.0E+04	930	Inv. ex.	
N	0.03	0.70	1.35	0.050	0.003	0.004	0.20	0.18	0.0035	0.0034	0.020	0.030	-	-	2.2E+04	827	Inv. ex.	
O	0.06	0.80	2.00	0.070	0.002	0.003	0.20	0.18	0.0031	0.0031	0.005	0.035	0.0020	-	1.9E+03	779	Inv. ex.	
P	0.06	0.15	1.00	0.100	0.003	0.002	0.30	0.18	0.0030	0.0030	0.005	0.030	-	-	8.5E+03	829	Inv. ex.	
Q	0.05	0.90	1.20	0.060	0.002	0.003	0.50	0.40	0.0025	0.0035	0.035	0.030	-	-	2.5E+04	837	Inv. ex.	
R	0.06	0.10	2.30	0.100	0.003	0.002	0.30	0.40	0.0016	0.0030	-	0.150	0.0020	-	3.5E+04	750	Inv. ex.	
S	0.07	0.80	0.60	0.060	0.005	0.002	0.20	0.18	0.0022	0.0015	0.026	-	0.0020	-	3.0E+03	877	Inv. ex.	
T	0.07	0.10	2.30	0.110	0.007	0.002	0.20	0.18	0.0033	0.0030	0.030	0.030	0.0020	-	9.0E+03	742	Inv. ex.	
U	0.08	1.40	0.60	0.060	0.004	0.002	0.20	0.18	0.0028	0.0030	-	0.010	0.0020	-	3.0E+04	772	Inv. ex.	
V	0.05	1.30	2.00	0.060	0.005	0.002	0.20	0.18	0.0032	0.0035	0.036	0.010	0.0020	-	1.2E+05	792	Inv. ex.	
W	0.13	1.00	2.20	0.070	0.002	0.002	0.20	0.18	0.0042	0.003	0.035	0.155	-	-	1.2E+04	733	Inv. ex.	
X	0.06	1.30	1.50	0.060	0.006	0.002	0.20	0.18	0.0033	0.0035	0.035	0.240	0.0020	-	2.0E+04	819	Inv. ex.	
Y	0.10	0.08	1.40	0.060	0.004	0.002	0.20	0.18	0.0029	0.003	-	0.010	-	0.0020	-	3.0E+04	772	Inv. ex.
Z	0.05	0.00	1.50	0.020	0.003	0.002	0.30	0.18	0.0022	0.0035	0.035	-	0.0020	-	3.0E+04	754	Comp. ex.	
a	0.04	0.90	2.50	0.060	0.005	0.003	0.008	0.008	0.0033	0.0035	0.020	-	2.9E+04	742	Comp. ex.			
b	0.05	0.40	1.90	0.060	0.012	0.002	0.20	0.18	0.0029	0.0032	-	0.010	0.0020	-	3.0E+03	774	Comp. ex.	
c	0.10	0.50	1.50	0.060	0.006	0.002	0.20	0.18	0.0018	0.0015	0.035	0.120	0.0020	-	1.1E+03	780	Comp. ex.	
d	0.04	0.80	1.50	0.060	0.005	0.003	0.20	0.18	0.0110	0.0110	0.034	0.015	-	-	1.0E+03	705	Comp. ex.	
e	0.06	1.20	2.10	0.060	0.003	0.003	0.20	0.18	0.0020	0.0020	0.030	0.030	0.0020	-	3.0E+03	778	Comp. ex.	
f	0.06	0.20	1.00	0.060	0.003	0.002	0.20	0.18	0.0032	-	0.010	-	0.0020	-	9.0E+02	837	Comp. ex.	
g	0.05	0.50	1.50	0.060	0.003	0.002	0.20	0.18	0.0030	0.0034	-	-	-	-	8.0E+03	788	Comp. ex.	

*Provided, however, that Ar₃ = 980-500(C% + 20.81Si%) - 63.5(Mn% + 23.9C%)

[0046]

[Table 4]

Steel	Final temp. °C	Cooling temp. °C/s	Air cooling start temp. °C	Air cooling time s	Coil- ing temp. °C	Tensile strength N/mm²	Elongation %	Hole expansion %	Corrosion sion mm	Corrosion sion mm	Remarks
D1	840	60	670	4	450	807	23	120	0.48	○	Inv. ex.
D2	870	60	—	—	550	597	26	130	0.48	○	Inv. ex.
E1	870	50	670	4	480	600	29	120	0.40	○	Inv. ex.
E2	870	60	—	—	550	605	27	125	0.39	○	Inv. ex.
F1	860	80	670	3	500	781	22	85	0.45	○	Inv. ex.
F2	870	60	—	—	550	786	21	90	0.44	○	Inv. ex.
F3	850	10	670	4	480	781	18	50	0.40	○	Comp.ex.
G1	880	60	670	3	450	588	29	120	0.41	○	Inv. ex.
G2	870	60	—	—	550	593	26	125	0.38	○	Inv. ex.
H1	890	60	680	3	450	811	21	85	0.42	○	Inv. ex.
H2	870	60	—	—	550	801	20	100	0.42	○	Inv. ex.
I1	850	60	680	3	510	692	25	100	0.41	○	Inv. ex.
I2	870	60	—	—	550	697	24	105	0.40	○	Inv. ex.
J1	870	50	670	3	480	787	23	85	0.43	○	Inv. ex.
J2	870	60	—	—	550	795	21	95	0.43	○	Inv. ex.
K1	860	60	680	3	500	799	22	80	0.43	○	Inv. ex.
K2	870	30	680	4	550	787	22	85	0.45	○	Inv. ex.
K3	850	50	680	5	300	797	23	50	0.42	○	Comp.ex.
K4	900	30	680	3	840	794	22	45	0.41	○	Comp.ex.
K5	870	70	690	6	490	799	17	60	0.47	○	Comp.ex.
K6	880	50	720	6	550	789	18	65	0.45	○	Comp.ex.
K7	880	10	680	3	500	779	18	60	0.42	○	Comp.ex.
K8	870	60	—	—	660	801	20	90	0.42	○	Inv. ex.
K9	880	10	—	—	480	786	18	60	0.40	○	Comp.ex.
L1	880	60	870	4	510	619	28	115	0.45	○	Inv. ex.
L2	870	60	—	—	550	634	26	120	0.44	○	Inv. ex.
M1	870	60	670	4	490	781	22	90	0.39	○	Inv. ex.
M2	870	60	—	—	550	791	20	100	0.39	○	Inv. ex.
N1	880	60	670	3	500	701	25	105	0.44	○	Inv. ex.
N2	860	50	680	5	300	711	25	55	0.43	○	Comp.ex.
N3	880	50	720	6	550	899	19	85	0.44	○	Comp.ex.
N4	870	60	—	—	550	714	23	110	0.47	○	Inv. ex.
N5	880	10	—	—	480	692	18	70	0.46	○	Comp.ex.
O1	860	60	670	3	500	825	22	75	0.48	○	Inv. ex.
O2	870	60	—	—	550	805	20	90	0.45	○	Inv. ex.
P1	860	60	680	3	510	618	28	110	0.41	○	Inv. ex.
P2	870	60	—	—	550	808	27	120	0.40	○	Inv. ex.
Q1	870	50	670	3	490	785	22	90	0.41	○	Inv. ex.
Q2	870	60	—	—	550	805	20	95	0.42	○	Inv. ex.
R1	860	60	680	3	500	799	22	90	0.40	○	Inv. ex.
R2	870	60	—	—	550	811	20	95	0.41	○	Inv. ex.
R3	880	40	—	—	700	798	20	55	0.42	○	Comp.ex.
S1	860	60	670	4	510	806	28	110	0.46	○	Inv. ex.
S2	870	60	—	—	550	598	27	125	0.45	○	Inv. ex.
T1	860	60	680	3	490	810	22	80	0.42	○	Inv. ex.
T2	870	60	—	—	550	815	19	90	0.41	○	Inv. ex.
U1	870	50	670	3	500	615	28	120	0.45	○	Inv. ex.
U2	870	60	—	—	550	805	27	125	0.47	○	Inv. ex.
V1	870	60	670	4	500	1012	16	55	0.44	○	Inv. ex.
V2	870	60	—	—	500	1002	15	80	0.48	○	Inv. ex.

W1	870	50	675	4	500	988	17	65	0.46	○	Inv. ex.
W2	870	50	-	-	500	980	17	60	0.45	○	Inv. ex.
X1	870	50	670	4	500	996	18	55	0.45	○	Inv. ex.
X2	870	50	-	-	560	993	15	60	0.47	○	Inv. ex.
Y1	870	50	670	4	550	610	28	115	0.42	○	
Y2	870	50	-	-	550	605	28	120	0.43	○	Inv. ex.
Z	870	60	-	-	450	596	22	70	0.70	×	Comp. ex.
a	880	70	680	5	510	830	15	50	0.68	×	Comp. ex.
b	850	40	660	5	490	654	20	70	0.46	○	Comp. ex.
c	880	70	-	-	600	810	10	50	0.43	○	
d	870	80	-	-	480	665	25	75	0.48	○	Comp. ex.
e	860	40	680	4	480	847	19	40	0.48	○	Comp. ex.
f	850	50	670	3	490	647	24	50	0.47	○	Comp. ex.
g	880	50	-	-	490	688	25	50	0.44	○	Comp. ex.

The corrosion depth was judged O (good) when the corrosion depth was less than 0.55 mm and was judged x (poor) when it was 0.55 mm or more.

[0047]

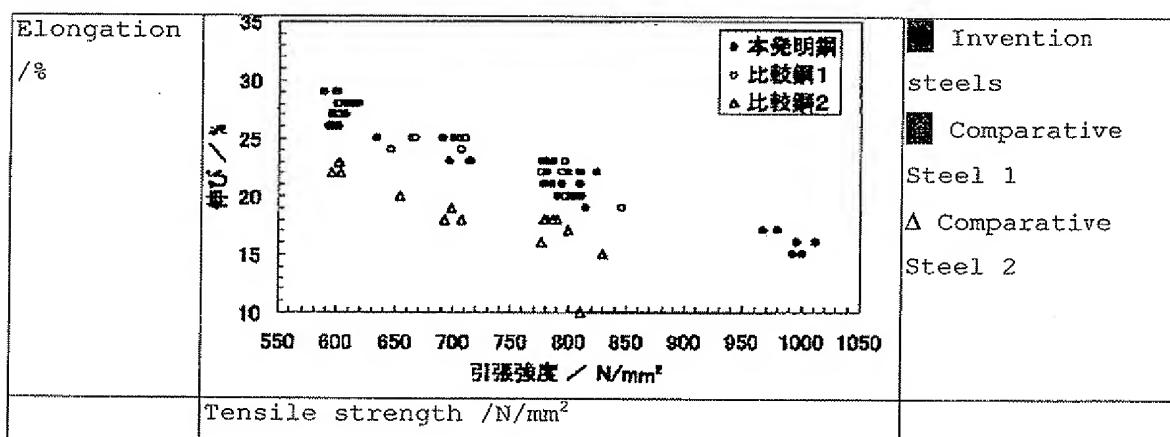
[EFFECTS OF THE INVENTION] According to the present invention, it becomes possible to supply low corrosion speed hot rolled high strength steel sheet having a strength level of the 590N/mm² class or more and having an unprecedented elongation-ductility balance, so this is extremely useful in industry.

[BRIEF DESCRIPTION OF THE DRAWINGS]

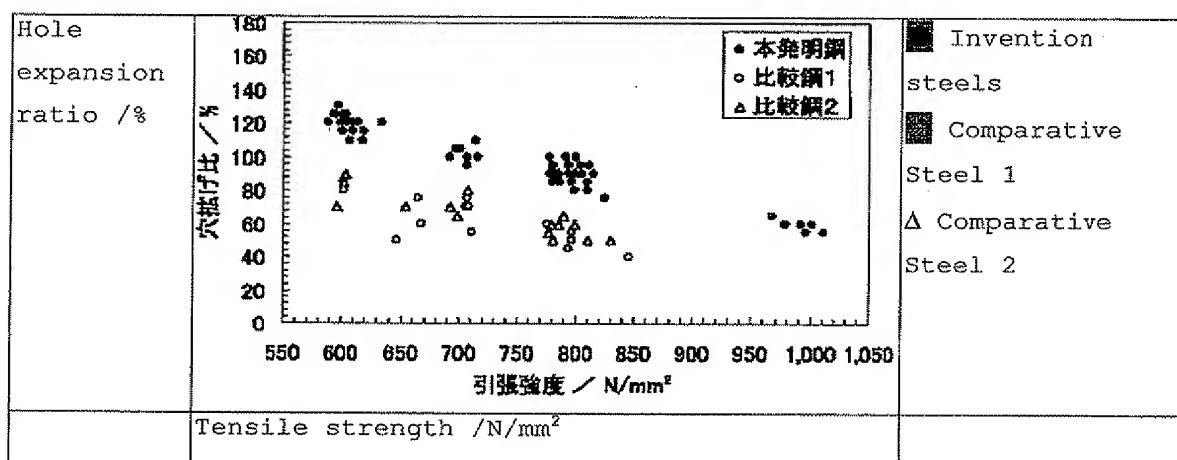
[FIG. 1] a graph showing the relationship between the tensile strength and elongation of invention steels and comparative steels.

[FIG. 2] a graph showing the relationship between the tensile strength and hole expansion ratio of invention steels and comparative steels.

[FIG. 1]



[FIG. 2]



[VOLUNTARY AMENDMENT]

[DATE OF SUBMISSION] January 12, 2001

[VOLUNTARY AMENDMENT 1]

[NAME OF DOCUMENT COVERED BY AMENDMENT] Specification

[NAME OF PARAGRAPH COVERED BY AMENDMENT] 0045

[METHOD OF AMENDMENT] Change

[CONTENT OF AMENDMENT]

[0045]

[Table 3]

Change steel "c", "0.10" to "0.21".